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LISTS OF SPECIES

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Species composition and morpho-ecological groups of aquatic macrophytes in foothill lakes on the eastern slope of the Southern Urals (Chelyabinsk region, Russia)

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Abstract: The aquatic macrophyte richness in nine lakes situated in the Chelyabinsk region (Russia) was analyzed. These lakes represent the foothill group, located on the eastern slope of the Southern Urals range. A total of 89 species belonging to 49 genera and 35 families were recorded. The species list includes 40 submerged rooted hydrophytes, 23 hygro-helophytes, 13 helophytes, 6 rooted hydrophytes with floating leaves, 4 free submerged hydrophytes and 3 free floating hydrophytes.

Key words: Aquatic macrophytes, species composition, morpho-ecological groups, foothill lakes, Southern Urals, Russia.

INTRODUCTION

The Chelyabinsk region is situated in the South Ural area, to the east of the southern part of the Ural range. This territory has a well developed hydrographic network, consisting of numerous lakes and rivers. There are more than 3,000 lakes in the region, occupying about 87,900 km².

Due to the area's varied topography, the lakes are very different in their morphological, hydrochemical and hydrological characteristics. The region lies in three natural zones – forest, forest-steppe and steppe. There are mountain lakes, foothill lakes and plain lakes. The macrophytes floristic composition and their community variety depend on the typology of the lakes. Until recently, the region has been rather poorly explored. A full species inventory has not been published.

The present study aims to provide an inventory of the aquatic macrophytes in model lakes, representing different types of foothill lakes, located on the eastern slope of the Southern Urals, in the Chelyabinsk region of Russia (Figure 1).

Very little botanical data has been published for these lakes. Some common information is contained in a manuscript (Tauson 1940) and in proceedings (Gornovsky 1961), but this material is incomplete and now outdated. Some lakes in Chelyabinsk were studied in 1978 by the Institute of Limnology (Leningrad, now St. Petersburg). Later, a book was published, containing some of I. A. Petrova's data on aquatic vegetation

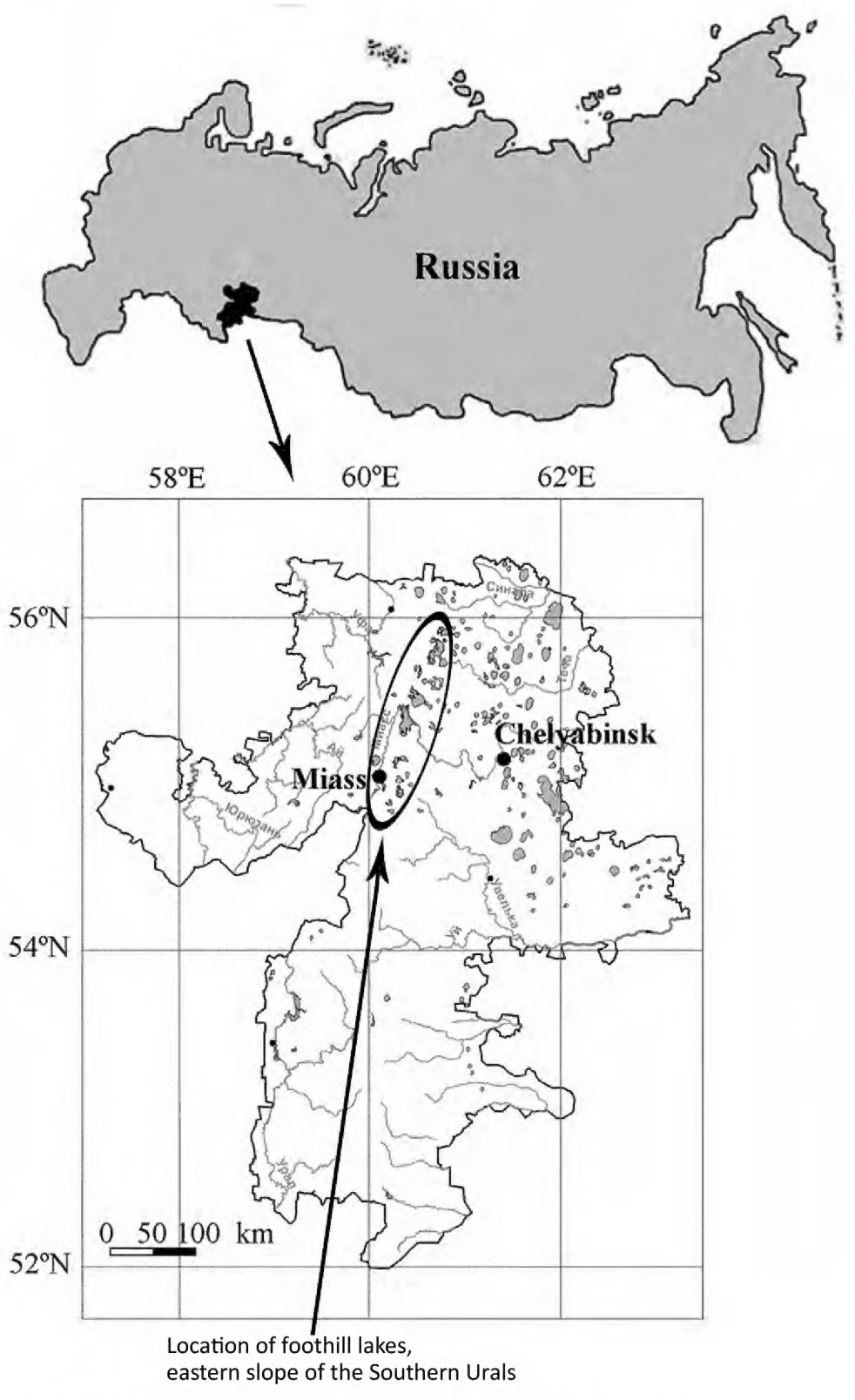

Figure 1. Location of foothill lakes in the Southern Urals.

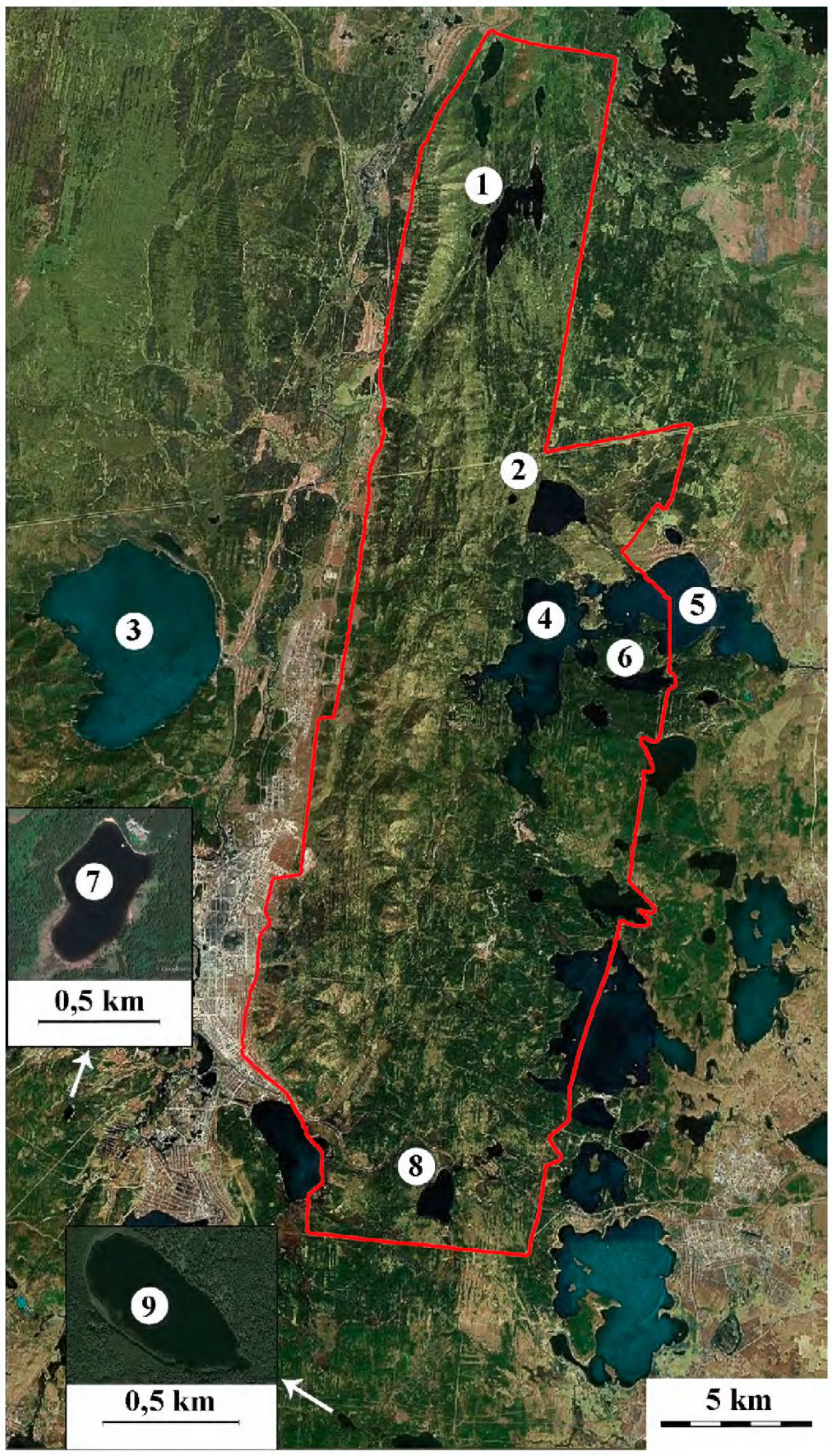

Figure 2. The study site and lakes: 1 – Big Ishkul, 2 – Big Tatkul, 3 – Turgojak, 4 – Big Miassovo, 5 – Small Miassovo, 6 – Baraus, 7 – Koshkul, 8 – Argajash, 9 – Small Elanchik.

(Drabkova et al. 1978), and in 1996, L. I. Shimansky investigated Turgojak Lake (Tkachev 1998). A book and several articles on this theme were published in Russian sources from 1999 to 2011 (Veisberg 1999, 2007, 2011; Veisberg and Isakova 2010).

The study site covers an area of 800 km² near the town of Miass (55°03′ N, 060°05′ E). This territory is characterized by complex relief. There are several mountain ranges extending to the south, with altitudes from 300 to 700 m above sea level. The study area belongs to the pine-birch forests subzone of the forest zone in the Southern Urals and adjoins the forest-steppe zone. The climate of the area is continental, characterized by strong differences between summer and winter. Average annual temperature has been about 2.5°C for the last 10 years, the warmest month is July (19–20°C, maximum reaching to 37°C), and the coldest month is January (–13 to –14°C, minimum dropping below –40°C). The vegetative period (with average temperature more than 10°C) lasts from the beginning of May to the end of September. In summer, the average temperature is near 15–17°C. The average annual precipitation is about 430–440 mm. Most of the precipitation in the summer is rain (around 200 mm) and, from November to March, is snow.

MATERIALS AND METHODS

Nine lakes were included in this study. Lakes having sufficiently complete species lists were selected. Presumably, they reflect the variety of habitats and floristic variety of this group of lakes (Figure 2). Another reason for this choice is that these lakes are in protected natural areas. Big Ishkul, Big Tatkul, Big Miassovo, Baraus, and Argajash lakes are in the territory of the Ilmen State Natural Reserve, while Turgojak, Koshkul and Small Ealnchic lakes are in regional nature sanctuaries. Small Miassovo Lake only partly belongs to the reserve, but it is connected to Big Miassovo as a joint hydrological system. Thus, anthropogenic impact on these lakes is minimal. This mainly concerns Turgojak and the eastern part of Small Miassovo, on the banks of which lie a few villages and small resorts. There is no industrial pollution, and the main anthropogenic factor is recreation pressure.

All studied lakes are of tectonic origin, but differ in morphological parameters (Table 1, Figure 2). They are all fresh; salinity ranges from 87 to 246 mg/l, main ions are HCO_3^+, Ca^{2+}, Mg^{2+}; pH is 6.5–8.0 (Andreeva 1973; Drabkova et al. 1978; Tkachev 1998;, Rogozin and Tkachev 2000). The water flow is slow. Because of distinctions in size, depth, coastline and bottom configuration, and multiplicity of underlying rocks, these water bodies are not exactly identical in their chemical composition and soil properties. Shallow lakes are characterized by silty (partly sandy) bottoms and swampy shores (Big Tatkul, Argajash, Small Elanchik and Koshkul). Others are deeper, having more complex coastlines and diverse rocky, sandy, and silty bottoms (Big Ishkul, Small Miassovo

Table 1. Characteristics of foothill lakes of the eastern slope of the Southern Urals.*

Lakes	Area, km²	Depth, m maximum/average	Salinity, mg/l
Big Ishkul	2.55	15.0/7.9	129.7-134.5
Big Tatkul	2.45	6/2	164-170
Turgojak	26.4	34/19.2	87-115.7
Big Miassovo	11.4	25/11.2	192.7-202.4
Small Miassovo	11.6	8.5/4.1	192.7-201.6
Baraus	1.38	10.5/5.5	320.8
Koshkul	0.13	6/4	223.6-246
Argajash	1.41	5.9/3.2	118.8-156
Small Ealnchik	0.18	3/1.3	135.6-148

*According to Andreeva (1973); Drabkova et al. (1978); Tkachev (1998); Rogozin and Tkachev (2000).

and Baraus). Big Miassovo and Turgojak are the deepest (Table 1). Their shorelines are mostly rocky; the littoral zone is narrow, except for shallow bays. The temperature of the surface layer (2 m) varies from 15–25°C in summer. The period of development of aquatic vegetation occurs from late May to late September, reaching a maximum in July to August. From November to April, the lakes are covered with ice.

Big Ishkul, Big Miassovo, Big Tatkul and Argajash lakes were investigated in July to August, from 1990 to 2013. A variety of different habitats and plant communities were observed. Results were partially published (Veisberg 1999). Herein, significantly supplemented and corrected material is represented. *Zannichellia repens*, *Potamogeton alpinus* and *P. filiformis* from Big Miassovo were described by Gornovsky (1961). Other species are confirmed by new herbarium specimens. Small Elanchic, Koshkul, Baraus and Small Miassovo were researched from 2008 to 2010. Data on these lakes are new. In total, about 250 specimens were collected. All voucher specimens are deposited in the Herbarium of Ilmen Nature Reserve of the Urals Division of RAS. Data on Turgojak Lake were taken from the literature (Tkachev 1998), except for *Isoëtes lacustris* L.

The verification of nomenclature and citation of authors of species found was carried out using the list of species of vascular flora of the Chelyabinsk region by Kulikov (2005) and the keys to stoneworts by Gollerbach and Krasavina (1983). For moss determination we used data by Isakova (2009).

RESULTS AND DISCUSSION

Vegetation is well developed in the foothill lakes of the Southern Urals. In big, deep lakes, it occupies the littoral band and shallow bays. In other types of lakes, plants spread almost over the entire area. Generally, macrophytes grow to a depth of 4–5 m. Coverage varies from 20–100%.

In total, 87 aquatic macrophytes specie from 48 genera and 34 families were found in nine different lakes (Table 2). The most representative flora registered were Magnoliophyta. The richest families were Potamogetonaceae, Cyperaceae, and Ranunculaceae. On the other hand, Charophyta, Bryophyta, Equisetophyta, Polypodiophyta and Lycopodiophyta were insignificantly represented.

All species were divided into morpho-ecological groups according to Papchenkov (1985) (Table 2). Following this classification, we agree that hygro-helophytes should be included among the aquatic macrophytes, as they are closely linked to the water environment.

The most representative plants are submerged rooted hydrophytes (39 species). Less numerous groups are hygro-helophytes (22 species) and helophytes (13 species). The least rich are rooted hydrophytes with floating leaves (6 species), free submerged hydrophytes (4 species) and free floating hydrophytes (3 species). Thus, overall, hydrophytes were more numerous than amphibious plants.

The investigated lakes are not exactly similar in quantity, composition and frequency of macrophytes (Table 2).The majority of the aquatic macrophytes were found in the mesotrophic lake, Big Miassovo (78 species, 89%). This is a result of the wide variety of biotopes in the lake, as well as the complex shape of the lake basin and its rugged coastline. It is characterized by relatively high diversity of Charophyta and the presence of rare species for the region (*Chara strigosa, Warnstorfia fluitans, Zannichellia repens, Caulinia flexilis, C. tenuissima*). Other, especially small, lakes have less diverse flora. The species numbers were as follows: Small Miassovo, 67; Big Ishkul, 51; Koshkul, 43; Small Ealnchik, 42; Baraus, 40; and Argajash, 43. This can be explained by less diverse habitats and natural processes of eutrophication. Floristically poorest is the shallow eutrophic-hypertrophic Big Tatkul Lake (24 species). The vegetation is well-developed in this lake and covers almost the whole water area, but it is very homogeneous. On the other hand, the oligo-mesotrophic Turgojak Lake, also characterized by a small number of species is, however, rather different from the previous one in composition. It is a deep lake with a narrow littoral band (mainly rocky and sandy) and sparse vegetation. Here, the very rare *Isoëtes lacustris* was found, indicating water purity. Among other rare plants, *Najas marina,* found in the Baraus Lake should be noted. It is the second record for the Chelyabinsk region (Veisberg, 2011).

About 11% of species were common for all lakes and approximately 20% were found in seven or eight lakes.

As for plant communities, about 30 species were main dominants (Table 2). However, only a few of these were common to all lakes. The most common dominants were *Phragmites australis*, *Typha latifolia*, *Nuphar lutea*, *Persicaria amphibia*, *Potamogeton lucens*, *P. perfoliatus*, *Myriophyllum sibiricum* and *Stratiotes aloides*. In Turgojak, Big Miassovo and Baraus lakes, some Charophyta species were also common dominants.

Differences in species diversity of macrophytes and their communities between investigated lakes were mostly due to natural factors such as characteristics of underlying rocks and soils, as well as morphological, hydrological and chemical features.

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Table 2. Species list and morpho-ecological groups of aquatic macrophytes found in foothill lakes of the eastern slope of the Southern Urals (Chelyabinsk region, Russia). Lakes: BI – Big Ishkul, BT – Big Tatkul, T – Turgojak, BM – Big Miassovo, , SM – Small Miassovo, B – Baraus, A – Argajash, K – Koshkul, SE – Small Elanchik.

Family/species	Lakes	Morpho-ecological group**	Voucher numbers
Charophyta			
Nitellaceae			
1. *Nitella opaca* (Bruz.) Ag.	T, BM, SM	Sr	1033/1 (a, b)
Nitellopsidaceae			
2. *Nitellopsis obtusa* (Desv. in Lois.) Gr.	BM*, SM*	Sr	1033/2 (a, b)
Characeae			
3. *Chara aspera* Willd.	BM*, SM, B*, A	Sr	1033/3 (a-d)
4. *Ch. fisheri* Mig.	T*	Sr	***
5. *Ch. fragifera* Durieu	BM	Sr	1033/4
6. *Ch. fragilis* Desv.	T, BM	Sr	1033/5
7. *Ch. locuples* Hollerb.	T*, B, A	Sr	1033/6 (a, b)
8. *Ch. rudis* A. Br.	SM	Sr	1033/7
9. *Ch. strigosa* A. Br.	BM	Sr	1033/8
10. *Ch. tomentosa* L.	BM*, SM*, B*	Sr	1033/9 (a-c)
Bryophyta			
Fontinaliaceae			
11. *Fontinalis antipyretica* Hedw.	T, BM*, SM	Sr	1033/10 (a, b)
Calliergonaceae			
12. *Warnstorfia fluitans* (Hedw.) Loeske	BM	Sr	1033/11
Lycopodiophyta			
Isoëtaceae			
13. *Isoëtes lacustris* L.	T	Sr	1033/12
Equisetophyta			
Equisetaceae			
14. *Equisetum fluviatile* L.	BI, BT, BM*, SM, B, K, A*, SE	H	1033/13 (a-h)
Polypodiophyta			
Thelypteridaceae			
15. *Thelypteris palustris* Schott	BI*, BT*, BM*, SM*, B*, K, A*, SE*	Hg	1033/14 (a-h)
Magnoliophyta			
Typhaceae			
16. *Typha angustifolia* L.	BI, BT, BM*, SM, B, K, A, SE	H	*****
17. *T. latifolia* L.	BI*, BT, BM*, SM, B*, K*, A*, SE*	H	*****
Zannichelliaceae			
18. *Zannichellia repens* Boenn.	BI, BM	Sr	1033/15
Najadaceae			
19. *Caulinia flexilis* Willd.	BM	Sr	1033/16
20. *C. tenuissima* (A. Br. ex Magnus) Tzvel.	BM	Sr	1033/17
21. *Najas marina* L.	B	Sr	1033/18

Continued

Table 2. *Continued.*

Family/species	Lakes	Morpho-ecological group**	Voucher numbers
Sparganiaceae			
22. *Sparganium emersum* Rehm.	BI, BM*, SM*, B, K, A, SE	H	1033/19 (a-g)
23. *S. erectum* L.	BI, BM, SM	H	1033/20 (a-c)
24. *S. microcarpum* (Neum.) Raunk.	BM, SM	H	1033/21 (a, b)
Potamogetonaceae			
25. *Potamogeton alpinus* Balb.	BM, SE	Sr	1033/22
26. *P. berchtoldii* Fieb.	BM, SM, B, K, A, SE	Sr	1033/23 (a-f)
27. *P. compressus* L.	BI, BT BM, SM, B, K*, A, SE	Sr	1033/24 (a-h)
28. *P. crispus* L.	BI, T, BM, SM, B	Sr	1033/25 (a-d)
29. *P. filiformis* Pers.	BM	Sr	****
30. *P. friesii* Rupr.	BI, BM, SM, B, A	Sr	1033/26 (a-e)
31. *P. gramineus* s. l.	BI, T, BM, SM	Sr	1033/27 (a-c)
32. *P. lucens* L.	BI*, T, BM*, SM*, B*, K*, A*, SE*	Sr	1033/28 (a-g)
33. *P. natans* L.	BI, BT, T, BM, SM, B, K*, A, SE*	Fr	1033/29 (a-h)
34. *P. obtusifolius* Mert. Et Koch	BI	Sr	1033/30
35. *P. pectinatus* L.	BM, SM, B*, K, A	Sr	1033/31 (a-e)
36. *P. perfoliatus* L.	BI*, BT*, T, BM*, SM*, B*, K, A*, SE*	Sr	1033/32 (a-c)
37. *P. praelongus* Wulf.	BI, T, BM, SM, SE	Sr	1033/33 (a-d)
38. *P. pusillus* L.	BI, BM, SM, B, K, A, SE	Sr	1033/34 (a-g)
39. *P. rutilus* Wolfg.	T, BM	Sr	1033/35
40. *P. trichoides* Cham et Schlecht.	BI, T, K	Sr	1033/36 (a, b)
Alismataceae			
41. *Alisma gramineum* Lej.	BI, T, BM, SM	H	1033/37 (a-c)
42. *A. plantago-aquatica* L.	BI, BT T, BM, SM, B, K, A, SE	H	*****
43. *Sagittaria sagittifolia* L.	BI, BM*, SM, K, A, SE	H	1033/38 (a-f)
Butomaceae			
44. *Butomus umbellatus* L.	BI, BM*, B, SM, K	H	1033/39 (a-e)
Hydrocharitaceae			
45. *Elodea canadensis* Michx.	BI, BT, T, BM, SM*, B*, K, A*, SE*	Sr	1033/40 (a-h)
46. *Hydrocharis morsus-ranae* L.	BI, BT, SM, BM, B, K, A, SE	Ff	1033/41 (a-h)
47. *Stratiotes aloides* L.	BI*, BT*, T, BM*, SM*, B, K*, A*, SE*	Sf	1033/42 (a-h)
Poaceae			
48. *Glyceria maxima* (C. Hartm.) Holmb.	BI, BM	H	1033/ 43 (a, b)
49. *Phragmites australis* (Cav.)Trin. ex Steud.	BI*, BT*, T*, BM*, SM*, B*, K*, A*, SE*	H	*****
50. *Scolochloa festucacea* (Willd.) Link	BI, BT, BM, B, SM, K, A, SE	H	1033/44 (a-h)
Cyperaceae			
51. *Carex acuta* L.	BI, BT, BM, SM, B, K*, A, SE	Hg	1033/45 (a-h)
52. *C. rhynchophysa* C. A. Mey.	BM, SM, K*	Hg	1033/46 (a-c)
53. *C. riparia* Curt.	BI, BT, BM, SM, A	Hg	1033/47 (a-e)
54. *C. rostrata* Stokes	BI, BM, SM, K, A, SE*	Hg	1033/48 (a-f)
55. *C. vesicaria* L.	BM, SM, K*, SE*	Hg	1033/49 (a-f)
56. *Eleocharis acicularis* (L.) Roem. et Schult.	BM, SM	Hg	1033/50 (a, b)
57. *E. mamillata* Lindb. Fil.	BM, SM, K, A*	Hg	1033/ 51 (a-d)
58. *E. palustris* (L.) R. Br.	BM, SM, K, A	Hg	1033/ 52 (a-d)
59. *Scirpus lacustris* L.	BI*, BM*, SM*, B*,K, A*, SE	Hg	1033/ 53 (a-g)
Araceae			
60. *Calla palustris* L.	BI, BT, BM, SM, B, K, A, SE	Hg	1033/ 54 (a-h)
Lemnacae			
61. Lemna trisulca L.	BI, BT, T, BM, SM, B, K, A, SE	Sf	1033/55 (a-h)
62. *L. minor* L.	BI, BT, T, BM, SM, B, K, A, SE	Ff	1033/56 (a-h)
63. *Spirodela polyrhiza* (L.) Schleid.	BI, BT, BM, SM, B, K, A, SE	Ff	1033/57 (a-h)
Polygonaceae			
64. *Persicaria amphibia* (L.) S. F. Gray	BI*, T, BM*, SM*, B*, K, A*, SE	Fr	1033/58 (a-g)
65. *Rumex aquaticus* L.	BI, BM, SM, K, A, SE	Hg	1033/59 (a-f)
Elatinaceae			
66. *Elatine hydropiper* L.	BM	Sr	1033/60
Nymphaeaceae			
67. *Nuphar lutea* (L.) Smith	BI*, BT*, BM*, SM*, B*, K, A*, SE*	Fr	1033/61 (a-h)
68. *N. pumila* Timm (DC).	BI, T, BM, SM, A, SE*	Fr	1033/62 (a-e)
69. *Nymphaea candida* J. & C. Presl.	BI, BM, SM, B*, K, A*, SE	Fr	1033/63 (a-g)

Continued

Table 2. *Continued.*

Family/species	Lakes	Morpho-ecological group**	Voucher numbers
70. *N. tetragona* Georgi	BI, BM, SM, SE	Fr	1033/64 (a-d)
Ceratophyllaceae			
71. *Ceratophyllum demersum* L.	BI, BT*, BM, SM*, B, K*, A, SE	Sf	1033/65 (a-h)
Ranunculaceae			
72. *Batrachium circinatum* (Sibth.) Spach	BI, BM*, SM*	Sr	1033/66 (a-c)
73. *B. eradicatum* (Laest) Fries	T	Sr	***
74. *B. trichophullum* (Chaix) van der Boskh.	T, BM	Sr	1033/67
75. *Caltha palustris* L.	BM, SM, SE	Hg	1033/68 (a-c)
76. *Ranunculus lingua* L.	K, B, SE	Hg	1033/69 (a-c)
Rosaceae			
77. *Comarum palustre* L.	BI, BT, BM, B, SM, K, A, SE	Hg	1033/70 (a-h)
Lythraceae			
78. *Lythrum salicaria* L.	BI, BT, T, BM, SM, B, K, A, SE	Hg	1033/71 (a-h)
Halorhagaceae			
79. *Myriophyllum sibiricum* Kom.	BI*, BT*, T, BM*, SM*, B, K*, A*, SE*	Sr	1033/72 (a-h)
Hippuridaceae			
80. *Hippuris vulgaris* L.	BI, BM, SM, K	Hg	1033/73 (a-d)
Apiaceae			
81. *Cicuta virosa* L.	BI, BT, BM, SM, B, K, A, SE	Hg	1033/74 (a-h)
Primulaceae			
82. *Naumburgia thyrsiflora* (L.) Rchb.	BM, SM, K, SE	Hg	1033/75 (a-d)
Lentibulariaceae			
83. *Utricularia vulgaris* L.	BI, T, BM, SM, K, A, SE	Sf	1033/76 (a-f)
Menyanthaceae			
84. *Menyanthes trifoliata* L.	BT, BM, SM B, SE,	Hg	1033/77 (a-e)
Callitrichaceae			
87. Callitriche hermaphroditica L.	BM, SM	Sr	1033/78 (a, b)
86. *C. palustris* L.	T, BM, SM	Sr	1033/79 (a, b)
Asteraceae			
87. *Petasites radiatus* (J. F. Gmel.) Toman	BM, SM	Hg	1033/80 (a, b)

*Dominant species.
**Hg – hygro-helophyte; H – helophyte; Fr – hydrophyte, rooted with floating leaves; Ff – hydrophyte, free floating; Sr – hydrophyte, submerged rooted; Sf – hydrophyte, free submerged.
***According to Tkachev (1998).
****According to Gornovsky (1961).
*****Not collected (very common, easy to identify species)